Contract Number W9132T-04-C-0017

ReliOn, Inc.

Final Project Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY03

Ft. Rucker, Alabama

August 31, 2006

Executive Summary

The CERL fuel cell installation at Ft. Rucker near Dothan, Alabama was one of three ReliOn demonstration sites funded under the BAA-FY03 program (CERL3). The other ReliOn demonstration sites were at Gabreski Air National Guard Base, Long Island, New York (1 unit at 4 kW) and Ft. Lewis, Washington (4 units at 1 kW each).

This project was intended to test the reliability of the ReliOn backup power solution for U.S. Military Air Traffic Control and Landing Systems (ATCALS) at Cairns Army Air Field at Ft. Rucker. The fuel cell systems were connected to the 24V or 48V DC bus at each site. The fuel cell systems were configured to monitor the commercial AC power grid as well as the status of the existing DC backup batteries at each site. Upon loss or failure of either power source, the fuel cells were designed to start automatically to provide up to 48 kWh of continuous run power to critical equipment at each site. In addition to providing continuous protection from a primary power failure, the installation was designed to simulate a 1-hour power failure in the AC grid each day.

Fuel cell equipment installation was completed in June 2004, but start-up of the systems was delayed until August due to poor telephone line communication to three of the four sites. Initial acceptance testing began on August 19, 2004 with limited test runs. Testing was ultimately halted in October 2004 with very little collection of useful operating data. Following initial interest, host personnel at Cairns Army Air Field (AAF) became somewhat less supportive of the project. This was compounded by poor data transmission and control with these sites and the distance of the Ft. Rucker location from a ReliOn service location. Cairns AAF personnel expressed unwillingness to provide further in-kind labor support to assist with system operational checks, gas deliveries, and during ReliOn maintenance visits.

After extended negotiations, the fuel cell equipment was removed from the test sites at Ft. Rucker in May 2006 and all sites were restored to their original states. In order to gain further information on the fuel cell equipment and bring a return on the installed cost expenditures, the project was redirected to perform extensive testing and analysis on the fuel cell cartridges returned from the test sites. Each I-1000™ fuel cell contains six cartridges which house the membrane electrode assemblies (MEA), forming the core of the ReliOn modular PEM fuel cell system. Between the curtailment of acceptance testing in 2004 and removal of the equipment in 2006, these cartridges remained dormant in a harsh environment for over 18 months, well beyond the quarterly exercise requirement designed to keep the MEA components conditioned and hydrated. Although initial restarts of these cartridges showed an extended time period (up to 18 hours in one case) to reach full power output, they could be fully reconditioned and returned to initial start-up and power output specifications.

Table of Contents

1.0 Descriptive Title

A demonstration of modular proton exchange membrane (PEM) fuel cells to serve as back up power for mission critical loads – ILS and other communication systems.

2.0 Name, Address and Related Company Information

Name: ReliOn, Inc.
Address: 15913 E. Euclid Ave., Spokane, Washington 99216
Phone: 509-228-6500
DUNS: 137264193
CAGE: 3K7Y7
Federal ID: 91-2191190

ReliOn, Inc., a privately held, small business, headquartered in Spokane, Washington, manufactures and markets proton exchange membrane (PEM) fuel cell products based on a unique and patented modular design. The company's current focus is on the sale and installation of highly reliable backup power solutions for critical applications within the telecom, utility and government/military markets.

ReliOn's offering helps customers increase network reliability while reducing overall equipment life-cycle costs in stationary, low power applications, typically requiring 200 watts to 5 kilowatts. Our air-cooled, self-hydrating fuel cells are highly reliable because we require only a minimal balance of plant and are able to bypass potential failure points. ReliOn, formerly Avista Labs, has been developing, demonstrating and marketing PEM fuel cell technology since 1995.

3.0 Production Capability of the Manufacturer

ReliOn, Inc., as described above, was the manufacturer and integrator of the primary products that comprised the backup power solution. These products incorporate the I-1000™, 1kW fuel cell systems, and the Outdoor Enclosure System which is designed to house the fuel cells, hydrogen fuel and fuel delivery system. ReliOn was responsible for installation and commissioning of the backup power solutions and performed all maintenance requirements via company applications engineers.

The I-1000™ Fuel Cell models and Outdoor Enclosure Systems are commercially available and offered under full warranty terms. ReliOn is currently (mid-2006) releasing its next generation fuel cell systems—the T-1000™ and T-2000™ products—which are substantially based on the I-1000™ product line. Until the end of 2004, ReliOn produced the I-1000™ product line through its contract manufacturer, Celestica, with production facilities in Fort Collins, Colorado. The fuel cell systems installed in this project were manufactured by Celestica. ReliOn currently has two contract manufacturers—Servatron producing circuit boards and control system subassemblies, and Logan Industries for final fuel cell assembly and integration into the Outdoor Enclosure system. Both of these firms are located within a 3 mile radius of ReliOn headquarters in Spokane, Washington, allowing easy interface and rapid problem solving. Production totaled approximately 500 I-1000™ fuel cells and 250 Outdoor Enclosure systems in 2005. With the release of the T-1000™ and T-2000™ products, these outputs are on track to double in 2006.

ReliOn's fuel cells are made from common materials using mature manufacturing processes in injection molded plastic, sheet metal fabrication and printed circuit board assembly. The membrane electrode assemblies (MEA) are purchased through a supply agreement with 3M.

4.0 Principal Investigator(s)

Mr. Gerry Snow
Product Manager
ReliOn
509-228-6682
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Mr. Russell Neff
Application Engineer
ReliOn
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5.0 Authorized Negotiator(s)

Mr. Frank A. Ignazzitto
Vice President, Government Sales
ReliOn
703-431-4858
509-228-6506
fignazzitto@relion-inc.com

6.0 Past Relevant Performance Information

ReliOn currently (mid-2006) has more than 200 fuel cell systems installed and operational in commercial applications covering 4 continents. Our fuel cell systems and backup power solutions have achieved numerous safety and performance certifications including; CSA, CE and NEBS Level III (telecom).

ReliOn's experience is inclusive of the following installations:

- **The Federal Aviation Administration;**
  - Palwaukee, IL, Radio Transmitter Receiver, December, 2003
  - Swinns Valley, WI, Microwave, June, 2004
  - Wakeman, OH, Microwave, August, 2004
  - Fargo, ND, RCAG, September, 2004
  - Average turn-key cost was approximately $35,000
  - Contacts: Mr. Stanley Lee, General Engineer, 847-294-8457; stanley.lee@faa.gov
    Mr. Steve Aldridge, Environmental Engineer, 952-997-9264; steve.aldridge@faa.gov

- **The Bureau of Reclamation;**
  - Loveland, CO, Microwave, October, 2003
  - System cost was approximately $15,000
  - Contact: Mr. Nathan Myers, Electrical Engineer, 303-445-2633 nmyers@do.usbr.gov

- **The States of Maryland and Ohio;**
  - 2 Sites in MD, 4 Sites in OH
  - E-911 radio equipment, August 2003 to October, 2004
  - Average turn-key cost was approximately $30,000 (no outdoor enclosure)
  - Contact: Mr. George Milne, COO, havePOWER, 202-299-0506 gmilne@havepower.com

7.0 Host Facility Information

Location

Ft. Rucker, Alabama

History

In 1973 all Army Aviation flight training was consolidated to Cairns Army Air Field at Fort Rucker. United States Air Force helicopter pilots have also been trained at Ft. Rucker since 1971. Initial rotary-wing courses to advanced courses in aviation safety are taught here.

Ft. Rucker

Contact:	Mr. Eugene P. Redahan, Sr.
Organization:	ATSCOM
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Email:	RedahanE@rucker.army.mil
Contact:	Mr. Ted Waters
Organization:	1-11th AVN
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Email:	waterst@rucker.army.mil

8.0 Fuel Cell Site Information

The project at Ft. Rucker was to consist of four individual installation sites – localizer, glide slope, middle marker beacon and outer marker beacon (below).

Localizer

Glide Slope

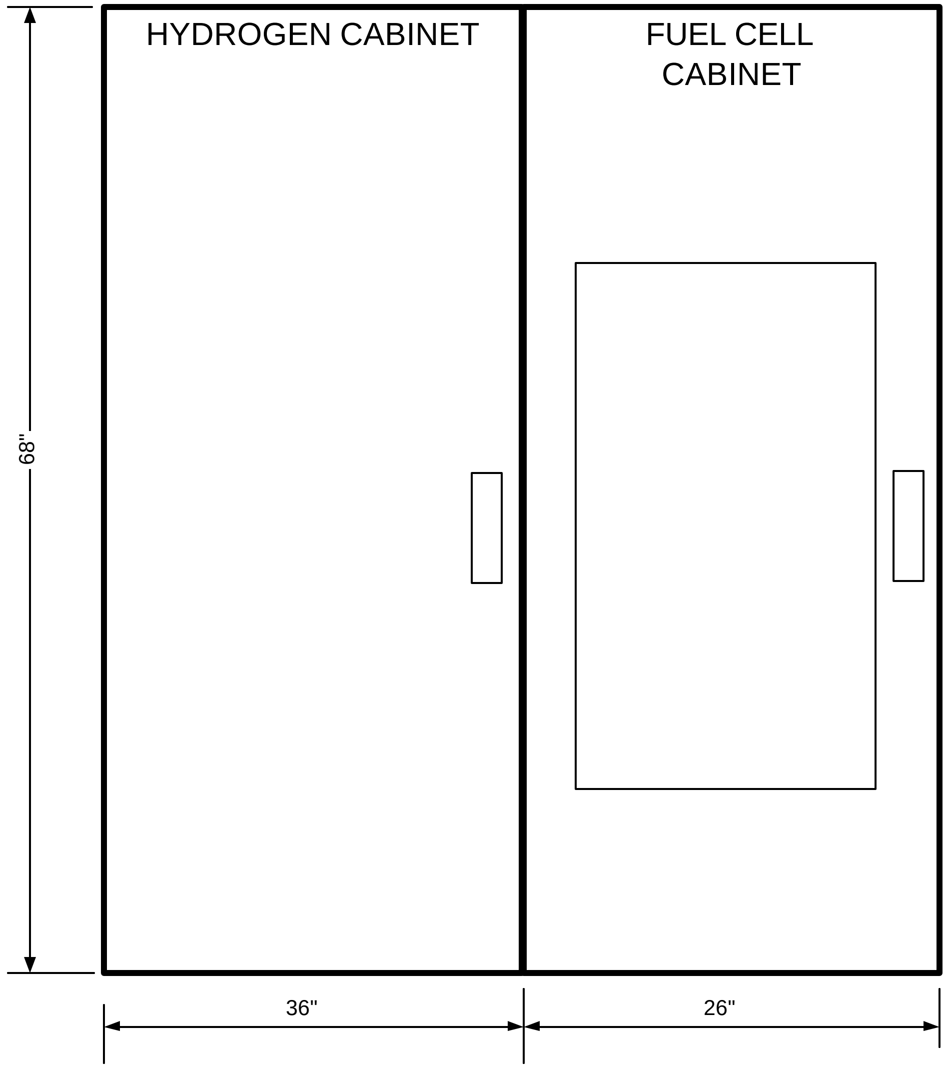
Middle Marker Beacon

Outer Marker Beacon

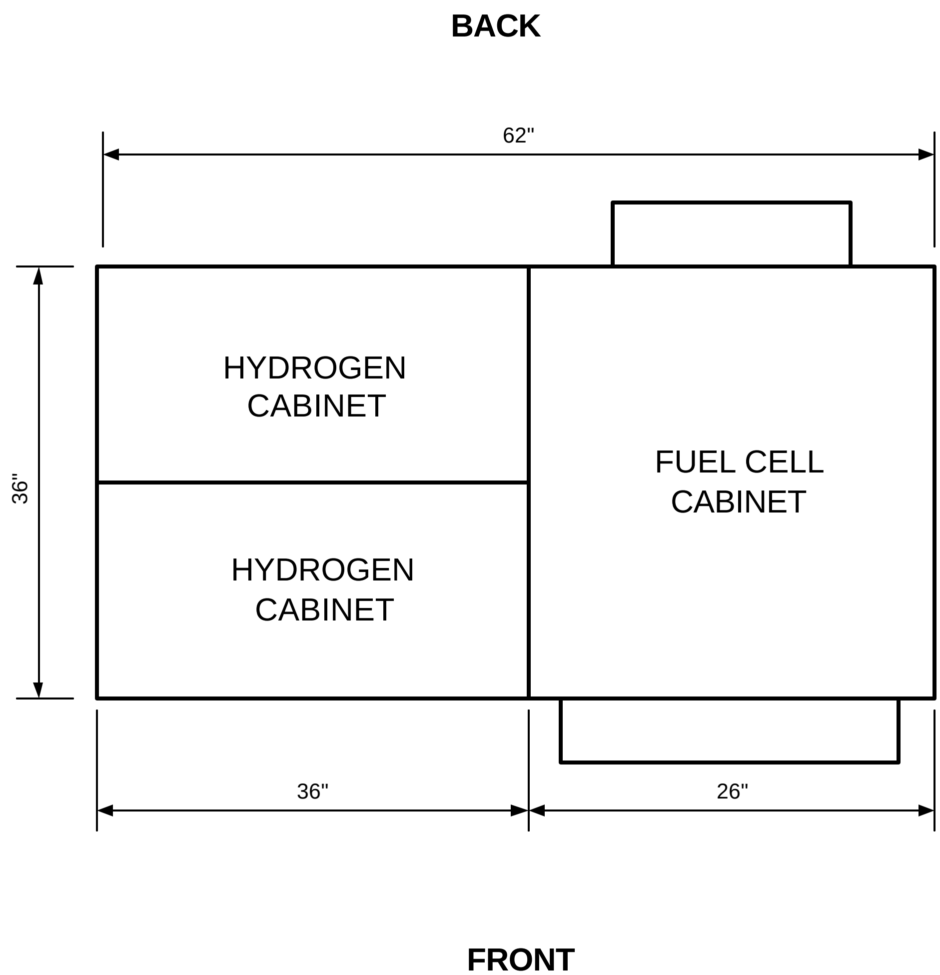
The localizer and glide slope were located on Cairns Army Air Field just outside of Ft. Rucker. The middle marker was located just outside of Cairns Army Air Field and the outer marker was located approximately 10 miles from Cairns Army Air Field near a peanut farm. Each site was to utilize one ReliOn Independence 1000 (1kW) fuel cell system as a source of backup power.

This project was to test the reliability of the ReliOn backup power solution for U.S. Military Air Traffic Control and Landing Systems (ATCALS). The fuel cell systems were to be connected to the DC bus at each site. The systems were to be in an off, but ready state the majority of the time. The system was designed to start up and run for one hour a day, to test the availability of the fuel cell system. Data was to be collected concerning start-up times, power availability, shutdown capability, system efficiencies, load following, and the effects of varying environmental conditions. If the system failed to start up properly or provide required power to the load this was to be noted in the logs as a failure and count against the 90% availability of the system.

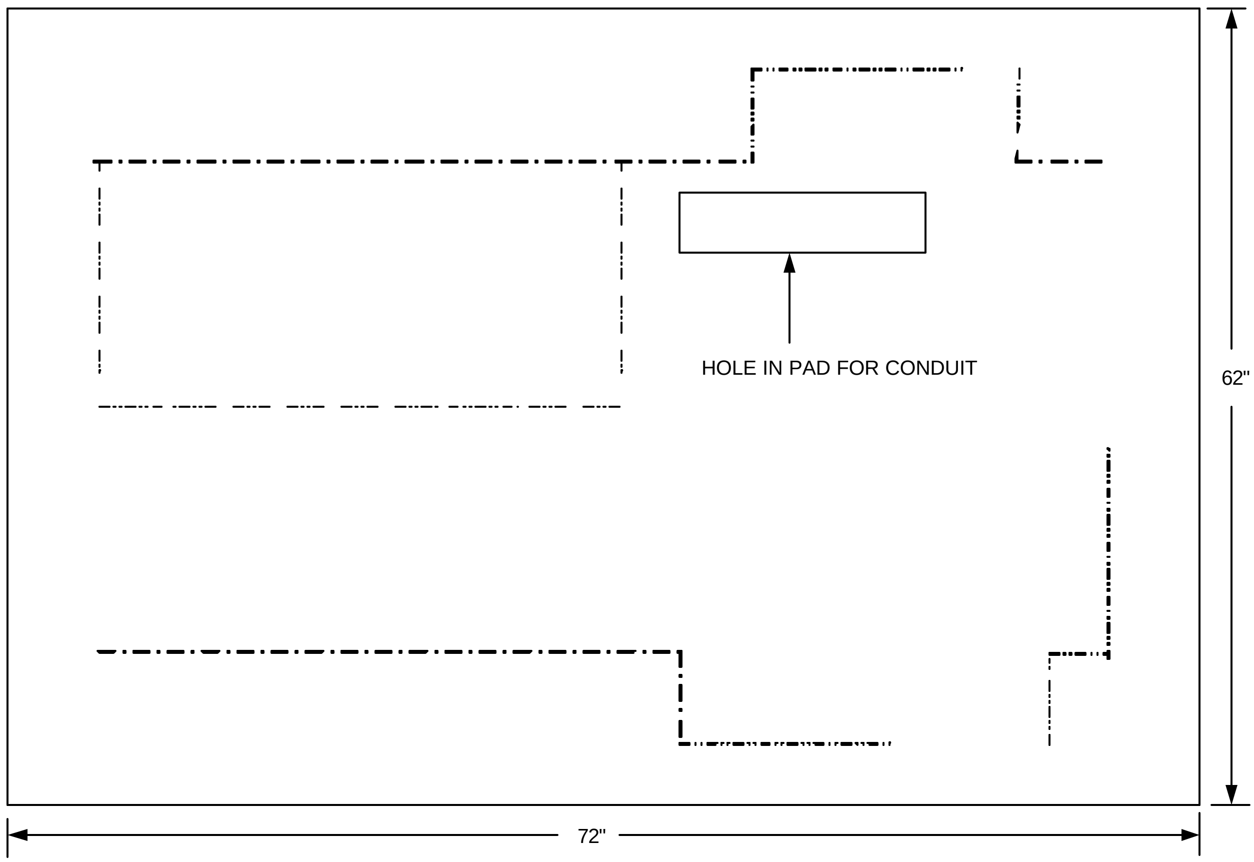
Because ReliOn's PEM fuel cells operate at low temperatures, the system was not a cogeneration system. The system was installed in an outdoor enclosure designed to maintain the internal temperature within the operating range of the Independence 1000.



ENCLOSURE FRONT VIEW



ENCLOSURE FOOTPRINT



COMPOSITE CONCRETE PAD FOOTPRINT

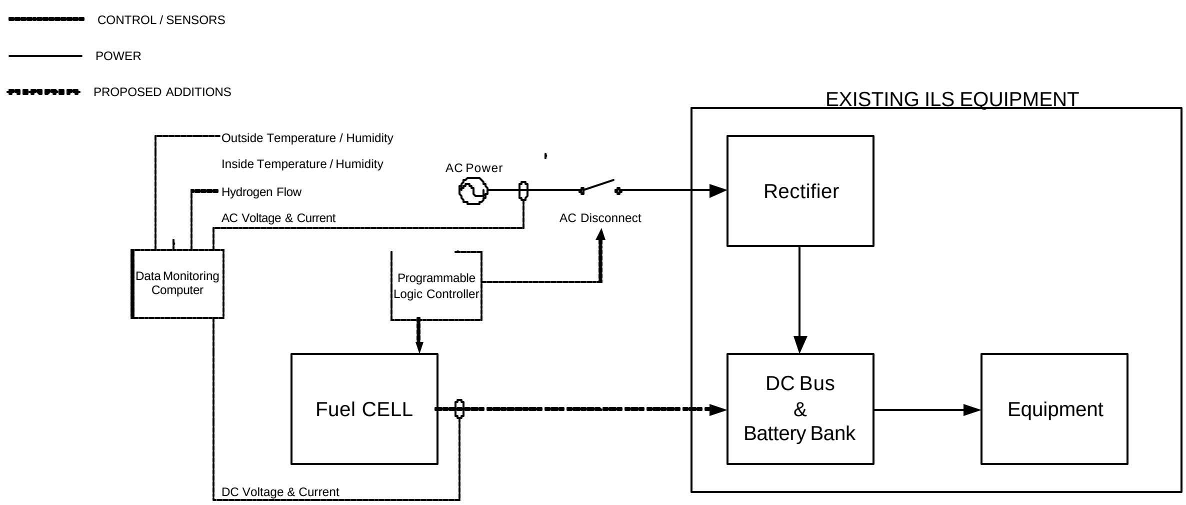
Integrated Fuel Cell and Hydrogen Storage/Delivery System:

- 2 Hydrogen Banks
- 6 cylinders total
- Each cylinder contains 197 cu-ft of hydrogen
- Total amount of hydrogen: 1182 cu-ft
- 40kW-hours of runtime capacity
- Composite Concrete Pad

The systems were to be fueled from industrial grade hydrogen gas. Compressed gas is the easiest and most commercially available source of industrial grade hydrogen. Each system was sited outdoors in an environmentally controlled enclosure placed on a composite concrete pad. The outdoor enclosure was provided by ReliOn included a locked hydrogen storage and delivery system which ensures that the compressed hydrogen bottles are protected and accessible only to authorized personnel.

On-Site maintenance was to consist of routine visual inspections and occasional equipment adjustments. The ReliOn Independence series is a system based on removable cartridges that house the PEM membranes. If a membrane were to fail, the system continues to operate and there is a visual indication, as well as remote indication capability with the communications system. When convenient, the failed cartridge can be replaced. This task can be accomplished in less than one minute without the use of tools.

9.0 Electrical System



SYSTEM FUNCTIONAL BLOCK DIAGRAM

At each of the four sites, the fuel cell systems were to run in a grid-independent mode with no interconnection requirements. All systems will be in a standby/ready mode to provide backup power for critical DC equipment when there is a loss of primary AC power. The Localizer, Glide Slope, and Middle Marker utilized one outdoor enclosure with one 24 VDC Independence 1000. The Outer Marker was set up to utilized one 24 VDC system for the Outer Marker ILS equipment and one 48 VDC system for the Compass Locator equipment. Electrical and communication connections between the fuel cell enclosure and each of the ATCAS shelters will be through dedicated conduit runs. All conduit runs were buried and the installation contractor gained all necessary permit approvals with the base.

See Appendix 1 for site specific connections

10.0 Thermal Recovery System

Not applicable.

11.0 Data Acquisition System

The load at each ILS shelter is between 50 watts and 200 watts. A Programmable Logic Controller (PLC) will be used to start the fuel cell once a day for a test period of one hour. The PLC will also energize a relay at the same time to disconnect AC power from the shelter rectifier.

A data acquisition system is also included in each enclosure to monitor and record the flowing:

- Inside temperature
- Inside Humidity
- Outside Temperature
- Outside Humidity
- AC Voltage at the site
- AC current at the shelter rectifier
- DC Voltage at the shelter DC bus
- DC current from the fuel cell

All vital information from the Independence 1000 was also to be monitored and recorded. The data-logging computer will be connected to the data acquisition module and fuel cell via Ethernet. The data-logging computer was to be configured to dial out an alarm during any of the following conditions:

- Loss of AC Voltage
- Low DC Voltage
- Hydrogen Sensor Alarm
- Fuel Cell Major Alarm
- Hydrogen Bank Empty
- Enclosure Fan Alarm

The system was also configured to start automatically during a loss of AC power and low voltage startup. The low voltage startup could have been configured for 23, 24 and 25 VDC startup thresholds for the 24 VDC system and 46, 48 and 50 VDC for the 48 VDC system.

12.0 Fuel Supply System

The fuel cell systems operate with industrial grade hydrogen gas. Compressed gas is the easiest and most commercially available source of industrial grade hydrogen. The outdoor enclosure included two locked hydrogen storage and delivery systems which ensured that the compressed hydrogen cylinders were protected and accessible only to authorized personnel. A sketch of the hydrogen compartments is shown in Figure 6.

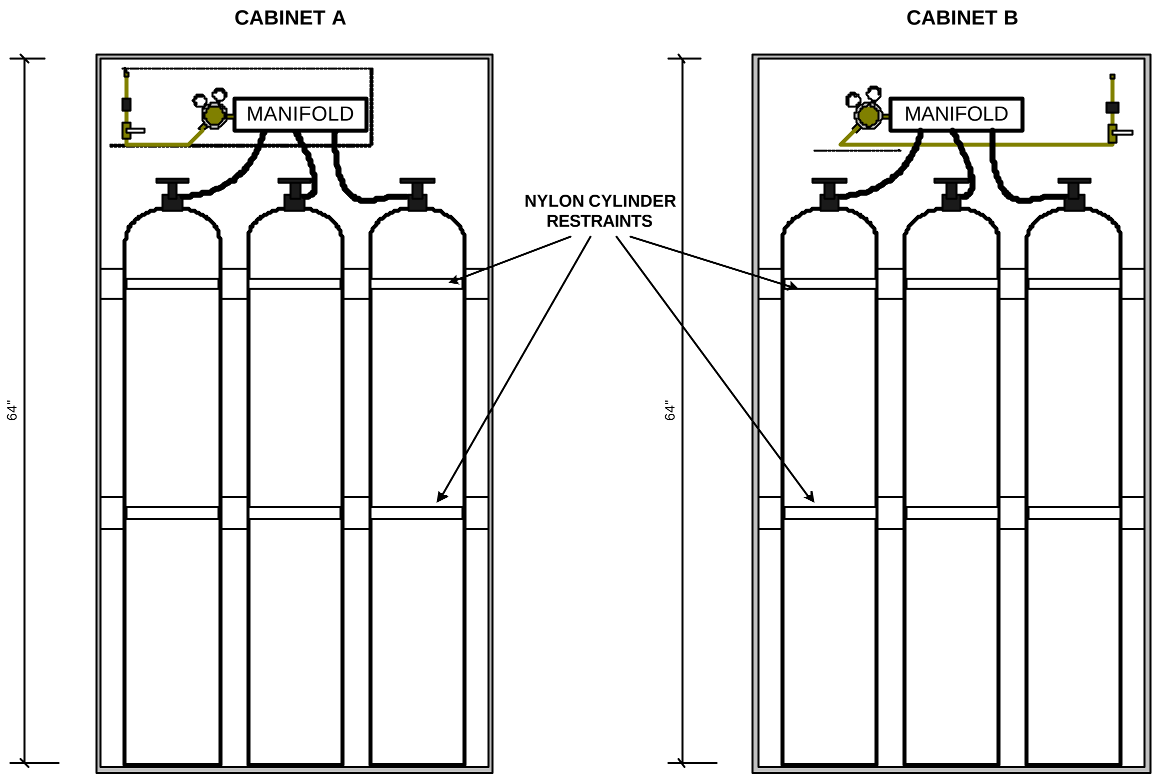


Figure 6. Hydrogen Fuel Compartments

The cylinders were typically size 300 (nominal 285 cu. ft or 8071 liter gas capacity at STP conditions), although size 200 could also be accommodated. Full cylinders were delivered with gas pressure at between 2000 and 2200 psig. Each of two hydrogen storage compartments contained three (3) cylinders directly connected into a high pressure manifold. The manifolds were each equipped with pressure switches and a regulator to reduce the gas pressure for delivery to the fuel cell. The pressure switches were monitored by the data logging computer which provided an alarm to the ReliOn personnel when the gas pressure fell to a pre-determined level. Hydrogen gas deliveries were made to each site by the local distributor for Airgas, Inc. at approximately 3 week intervals. Additional deliveries were scheduled as required to accommodate unplanned AC grid outages and extended test periods.

The optimal setting for the pressure regulators to the fuel cell was 40-50 psig. By adjusting the regulated pressures so that one bay is 5-10 psig higher than the other side, hydrogen was to be withdrawn from the higher pressure side until those cylinders were exhausted. The system then drew hydrogen from the other side allowing time to order and replace the depleted cylinders.

13.0 Installation Costs

Table 1 shows a breakdown of project costs for the ReliOn PEM fuel cell backup power demonstration project at Ft. Rucker. The total project proposed cost including ReliOn's profit and cost share for the entire contract was $363,781.64. Of this amount, $128,492 was allocated for the Ft. Rucker site.

Table 1. Project Costs for Contract Number W9132T-04-C-0017 (Ft. Rucker Site)

Task 1: Fuel Cell Power Plant		Plan			Actual Through End of Project
Direct Labor					
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Training			$300	$300
Equipment					
I-1000 Fuel Cell		2	$8,050	$16,100	$16,100
I-1000 Fuel Cell		3	$6,500	$19,500	$19,500
Enclosure w/2 Fuel Wings		4	$5,950	$23,800	$23,800
Task 1 Subtotal Budget				**$59,700**	**$59,700**
				Totals By Quarter ==>	

Task 2: Installation		Plan			Actual Through End of Project
General/Electrical Contractor					
General Contractor				$1,600	$1,600
Electrical Contractor				$3,200	$3,200
Materials & Expenses					
Crane/Fork Lift				$1,000	$1,000
Telecommunications				$22,400	$22,400
Task 2 Subtotal Budget				**$28,200**	**$28,200**

Task 3: Performance Monitoring		Plan			Actual Through End of Project
Direct Labor					
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Monitoring & Data Management			$2,600	$1,600
Principal Investigator	Monitoring & Data Management			$1,200	$800
Task 3 Subtotal Budget				**$3,800**	**$2,400**

Task 4: Maintenance		Plan			Actual Through End of Project
Direct Labor					
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	On Site Training			$300	$300
Applications Engineer	Remote & Site Maintenance			$800	$500
Principal Investigator	Remote & Site Maintenance			$0	$0
Task 4 Subtotal Budget				**$1,100**	**$800**

Task 5: Project Management & Reporting		Plan			Actual Through End of Project
Direct Labor					
Staff	Activity	Units	Unit Cost	Total Cost	
Project Manager	Management, Reporting, Meetings			$1,200	$900
Principal Investigator	Management, Reporting, Meetings			$800	$500
	Initial Project Description			$600	$600
	Monthly Status Report			$300	$130
	Midpoint Report			$600	$720
	Final Report			$600	$500
Task 5 Subtotal Budget				**$4,100**	**$3,350**

Table 1 (Continued)
Project Costs for Contract Number W9132T-04-C-0017 (Ft. Rucker Site)

Task 6: Travel		Plan			Actual Through End of Project
Managerial Travel				$2,411	$2,411
Technical Travel-Installation				$3,506	$364
Technical Travel-Maintenance				$7,656	$6,000
Technical Travel-Decommissioning				$2,776	$2,776
Task 6 Subtotal Budget				**$16,349**	**$11,551**

Task 7: Decommissioning/Site Restoration **Direct Labor**		Plan			Actual Through End of Project
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Site Work			$0	$3,200
Principal Investigator	Site Work			$0	$0
General/Electrical Contractor					
Labor				$3,200	$0
Materials & Expenses					
				$2,000	$2,000
Task 7 Subtotal Budget				**$5,200**	**$5,200**

Task 8: Other Costs **Equipment & Expenses**		Plan		Actual Through End of Project
Hydrogen Fuel			$6,080	$5,600
Electrical Equipment			$5,000	$5,000
De-hydrated cartridge testing from Contract Modification Request CERL-BAA-FY03			$0	$7,400
Task 8 Subtotal Budget			**$11,080**	**$18,000**

Ft. Rucker Total Budget	**$129,529**	**$129,201**
Profit (10%)	$12,953	$12,920
Ft. Rucker Total Project Cost	**$142,482**	**$142,121**
ReliOn Cost Share (10%)	($13,990)	($13,629)
Ft. Rucker Total Project Billing	**$128,492**	**$128,492**

14.0 Milestones/Improvements

See Section 16: Additional Research/Analysis

15.0 Decommissioning/Removal/Site Restoration

Upon completion of the test program, the NAVAIDS personnel at Cairns AAF requested that the test sites be restored to their original state. With assistance from the NAVAIDS technicians, this work was completed at the site by ReliOn Application Engineers during the week of May 24th, 2006.

The restoration effort involved removal of all test equipment and fuel cell components from within the fuel cell enclosures. The enclosures and the concrete mounting pads were removed by the NAVAIDS technicians.

All the fuel cell cartridges and I-1000™ systems were returned to ReliOn.

Included in the restoration was the removal of all the wiring and conduit into each of the shelters and the penetrations into the shelter were patched and sealed. Each site restoration was approved by the NAVAIDS personnel.

16.0 Additional Research/Analysis

Considering the sensitivities at Ft. Rucker, on April 20, 2006, Frank A. Ignazzitto, Vice President, Government Sales for ReliOn wrote Mr. Franklin H. Holcomb, U.S. Army Engineer Research & Development Center, Construction Engineering Research Laboratory a letter suggesting a no cost contract modification. ReliOn would extend the analysis of this fuel cell technology, which has been dormant but exposed to the external elements for over 12 months, by running tests, gathering data and reporting on our findings. The contract modification Request was approved and the following report (starting with 1.0 and ending with 8.3 below) was generated after testing of all Ft. Rucker cartridges.

1.0 Narrative:

1.1 The decommissioning of CERL III, Ft. Rucker, Alabama yielded qty (30) thirty Fuel Cell cartridges. These cartridges were nested in their respective J48, 24 VDC and 48 V fuel cell for **extended periods in the field without exercise cycling or use of any kind. ReliOn uses Proton Exchange Membranes (PEM) in its Fuel Cell Cartridges and these “membranes” require “hydration” or water to provide specified power output. The lack of use at CERL III, Ft. Rucker, resulted in the dehydration of cartridge membranes. There were (4) four different fuel cell locations at Ft. Rucker: Localizer, Glide Slope, Middle Marker and Outer Marker. CERL (Construction Engineering Research Laboratory) has authorized the use of remaining CERL III funds to conduct tests studying the performance of cartridges left dormant for extended periods.

1.2 The ReliOn Fuel Cell system for the CERL units being evaluated at the Ft. Rucker site were system specified to provide a combined or “system” power output of 1000 watts. There are six (6) cartridges in a J48 system; at 1000 watts, each cartridge would provide roughly an average of 166 watts “net” or available power to customer load.

1.3 **Characterization of Cartridge Hydration -**

1.3.1 **Startup time** – the time for converter output to reach 1 kW. A regular set cart with good hydration normally takes up to 20 minutes to reach net (converter) 1 kW.

1.3.2 **Cartridge ESR –** ESR (Equivalent Series Resistance) value is a measure of cartridges membrane hydration. A regular Rev 10 cartridge (revision 10 of our product turns) with good hydration has ESR values in the range of 27 to 32 mOhm.

2.0 Cartridge Detail:

Location at Ft Rucker	Qty	Serial Numbers	REV	**Time in field with no use
Localizer	6	3754, 3753, 3751, 3752, 3750, 3755	10	18 months (10/29/04 – 4/27/06)
Glide Slope	6	3417, 3432, 3436, 3435, 3433, 3434	10	18 months (10/29/04 – 4/27/06)
Middle Marker	6	3362. 3353, 3348, 3364, 3351, 3365	10	18 months (10/29/04 – 4/27/06)
Outer Marker	6	3163, 3164, 3165, 3167, 3169, 3171	10	18 months (10/29/04 – 4/27/06)
Outer Marker 48 V	6	3459, 3461, 3460, 3464, 3471, 3462	10	18 months (10/29/04 – 4/27/06)

3.0 Test Expectations:

3.1 At this time, performance expectations from dehydrated cartridges and the time taken to "re-hydrate" a de-hydrated Fuel Cell Cartridge is limited. During other testing, R&D internal to ReliOn has indicated diminished power output from "any" de-hydrated cartridge. However, the extent or affect de-hydration has on cartridges and the ability of any dehydrated cartridge to regain "as specified" levels of power output performance has been limited and/or unknown.

3.2 ReliOn has been selling Hydrogen Fuel Cell commercially for three years. Because of this fact, the availability for testing on "real world" dehydrated fuel cells has been limited. The data gathered from testing the Ft. Rucker cartridges will provide useful information now and reference points and comparison to future testing.

4.0 Objectives:

4.1 Covered in Element 1 testing – Characterization of 18-month field stored cartridges, especially, for the following properties:

4.1.1 The time from startup to reach net output 1 kW

4.1.2 The performance status after sufficient hydration.

4.1.3 Cartridge ESR (Equivalent Series Resistance) – a measure of cartridge membrane hydration

4.1.4 Assess any damage to the cartridges after 18-month storage in the units and in the field at Alabama.

4.2 Covered in Element 2 testing - Development of accelerated startup procedures. Apply an accelerated startup procedure (6% shunt) that was developed previously for dry cartridges. A **"shunt"** is ***Intentional electrical shorting*** *causing the ReliOn Fuel Cell membrane to increase the production of water providing increased power output.*

5.0 Scope:

The tests were split in **two elements**:

1. CERL Testing and reporting as called out under the heading of "**CERL TESTING**" in sections a, b, c & d below.
   1.1 ReliOn indicated in the Contract Modification Request that test data would be provided from the Converter, Bus at a Cartridge level as well as at a System level. While "re-hydration" testing performance with individual cartridges and bus power levels were favorable, it's relevant to note that ReliOn Fuel Cells are specified to it's customers at a "System" level and usable power is realized from the Converter, not the Bus.

2. Additional ReliOn tests non specific to any CERL testing requirements.

Element 1 - "CERL TESTING" - Contract Modification Request (CERL-BAA-FY03) Testing.

a. The time taken for an **individual Cartridge and the System** to provided specified power from startup.

   i. **Cartridge** from startup to provide 50 watts, 100 watts, ***220 watts - *Not performed, see letter A in Element 1,"DEHYDRATED CARTRIDGE TESTS" for explanation.*

      - *There are two power outputs in ReliOn Fuel Cells: Converter (net power) and bus (gross power) power.*

- *Converter power is the net power available to a customers load.*

- ****While is it is possible to attain 220 watts at the bus and the converter from an individual cartridge, ReliOn* ***expresses its performance results as a "system".***

- *Converter power is not specified or expected to continuously attain 220 watts from a single cartridge…though it can happen.*

- *There is* ***__no__*** *viewable power output for individual cartridge at the converter level.*

- *The time to power noted in the tests on an individual level should not be held to the 220 watt value as indicated in* CERL-BAA-FY03 *proposal.*

ii. **__System__** time from startup to provide 250 watts, 500 watts, 1000 watts.

b. Recondition cartridges and record recovery time

c. Post reconditioning tests.

i. Cartridge time from start to 50 watts, 100 watts, 220 watts – *Not performed, see section 6.1, A in Element 1 for explanation.*
ii. System time from start to 250 watts, 500 watts, 1000 watts

d. Submit confidential report.
i. Project system availability for dormant cartridges.
ii. Recommend appropriate exercise cycles.

Element 2 - Additional ReliOn Tests

a. Development of accelerated startup procedures.

6.0 Testing

6.1 Element 1 - DEHYDRATED CARTRIDGE TESTS

Dehydrated Cartridge Reporting

A. Cartridge - Bus

The Contract Modification Request (CERL-BAA-FY03) expressed that we would be evaluating cartridge time to three power outputs at the bus from a dehydrated and hydrated state. ***This was not performed beacsue ReliOn specifies its Fuel Cell performance as a system.

B. System – Bus

Cartridge Identifier	Time to 250 watts	Time to 500 watts	Time to 1000 watts
Glide Slope	**2 min 43 sec**	**8 min**	**5 hrs**
Middle Marker	**17 min**	**9 hrs 11 min**	**16 hrs 42 min**

C. System - Converter

Cartridge Identifier	Time to 250 watts	Time to 500 watts	Time to 1000 watts
Glide Slope	**2 min 40 sec**	**27 min**	**5 hrs 41 min**

Middle Marker	**2 hrs 31 min**	**9 hrs 40 min**	**18 hrs 9 min**

6.2 Element 1 - POST CONDITIONING CARTRIDGE TESTS

Reconditioned Cartridge Reporting:

D. Cartridge - Bus

See comments in under letter A. in the “Dehydrated Cartridge Reporting” section.

E. System – Bus

Cartridge Identifier	Time to 250 watts	Time to 500 watts	Time to 1000 watts
Glide Slope	**1 min**	**1 min 25 sec**	**14 min 30 sec**
Middle Marker	**1 min 20 sec**	**1 min 40 sec**	**19 min**

F. System - Converter

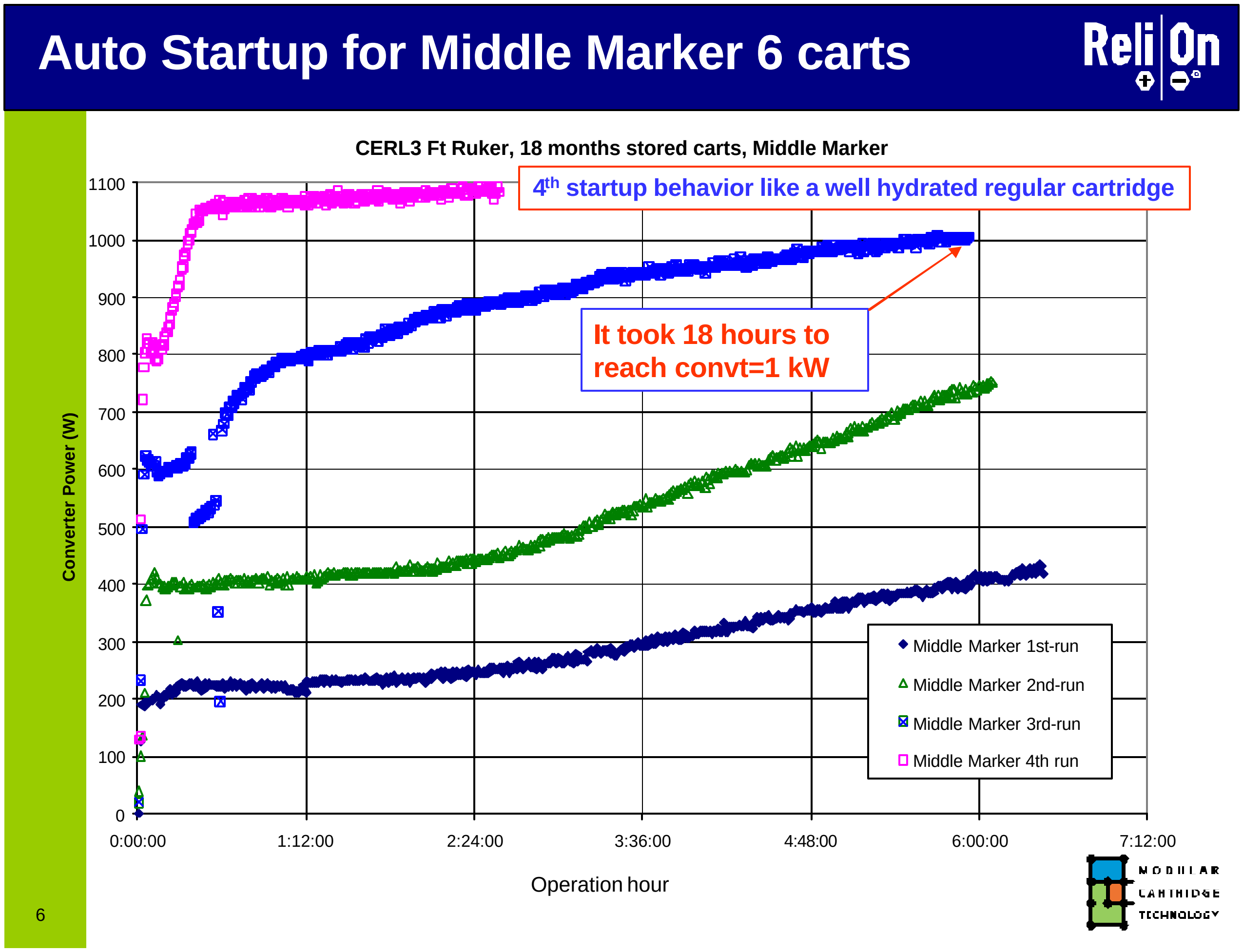
Cartridge Identifier	Time to 250 watts	Time to 500 watts	Time to 1000 watts
Glide Slope	**1 min 9 sec**	**1 min 30 sec**	**17 min**
Middle Marker	**1 min 22 sec**	**1 min 42 sec**	**22 min**

6.3 Graphical reporting - Expressed in two ways; Startup time and ESR.

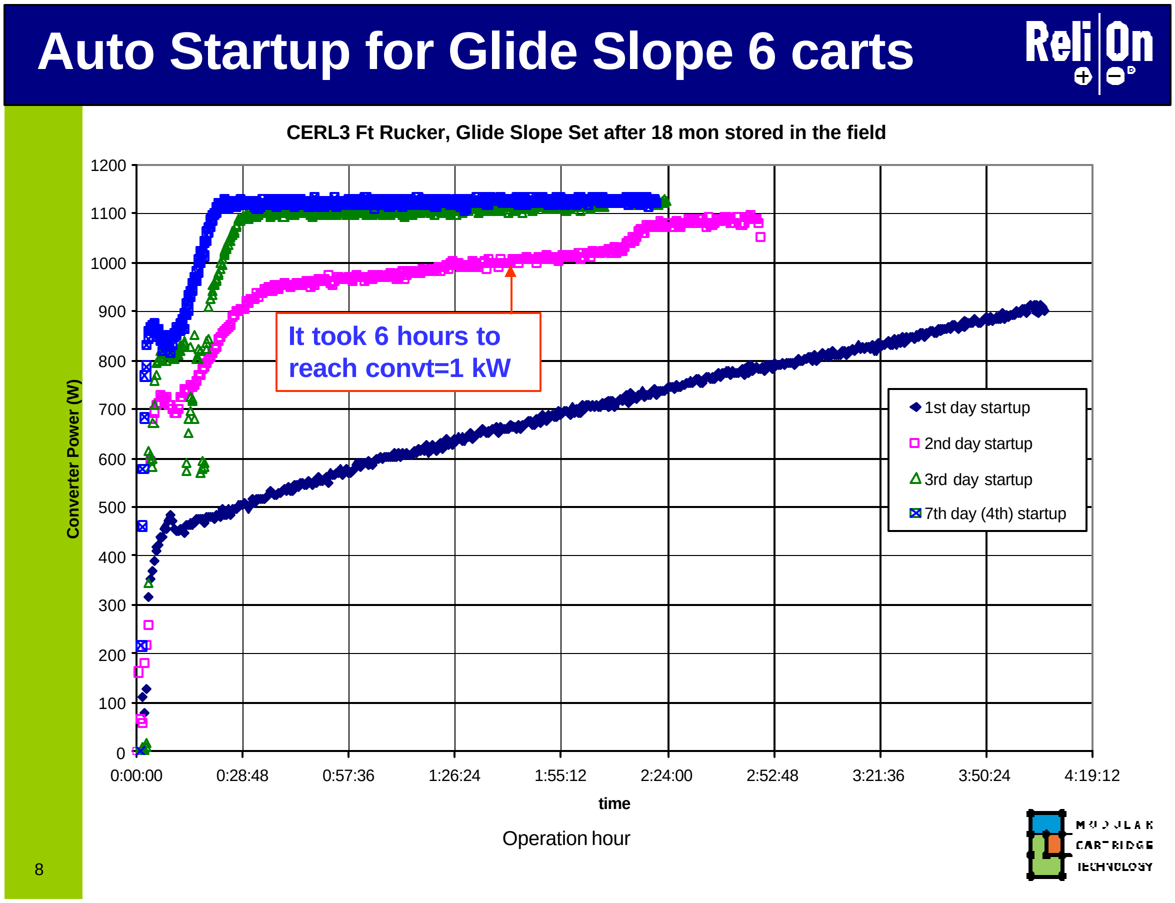
6.3.1 Startup time – the time for converter output to reach 1 kW. A regular set cart with good hydration normally takes up to 20 minutes to reach net (converter) 1 kW.

6.3.2 Cartridges ESR – ESR (Equivalent Series Resistance) value is a measure of cartridges membrane hydration. A regular Rev 10 cart with good hydration has ESR values in the range of 27 to 32 mOhm.

6.3.3 Graphical reporting for “Glide Slope” cartridges supporting Element 1 testing (See below graph).



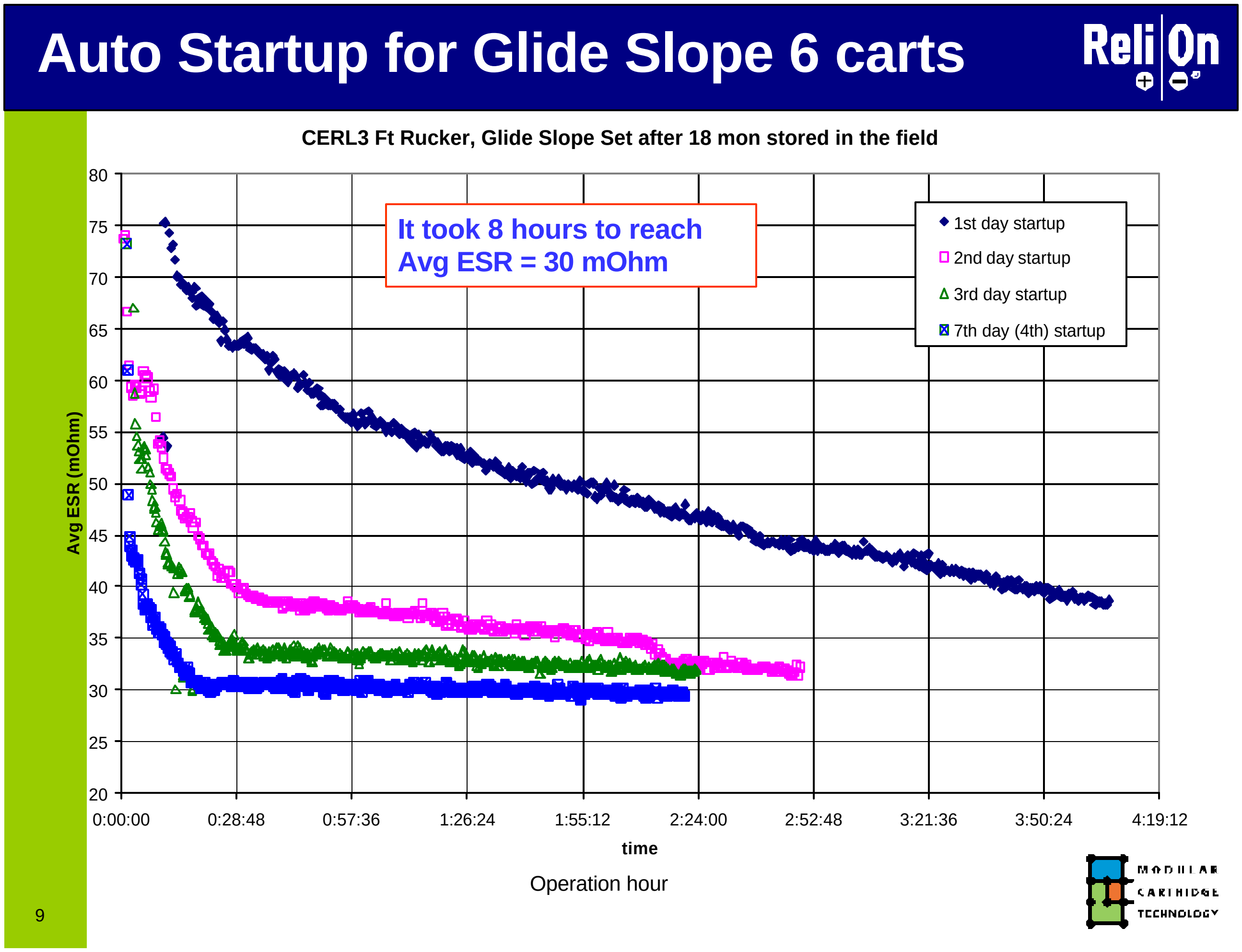
6.3.4 Graphical reporting for "Glide Slope" cartridges supporting Element 1 testing (See below graph).



6.3.5 ESR of all Ft. Rucker Fuel Cells

Glide Slope	Initial ESR	After Hydration ESR		Outer 24V	Initial ESR	After Hydration ESR
#3436	119	30.8		#3165	111	**38**
#3432	91	31.3		#3164	100	**35.3**
#3417	141	30.3		#3163	91	**34.9**
#3434	110	27.4		#3171	161	**40.7**
#3433	62	28.2		#3169	109	**38.4**
#3435	80	29.3		#3167	119	32
Middle Marker				Outer 48V		
#3362	198	30.7		#3460	187	31.2
#3365	178	26.2		#3459	88	30.4
#3351	207	27.8		#3461	87	32
#3364	120	28.9		#3464	146	32.4
#3348	70.8	26.4		#3462	130	29.7
#3353	180	27		#3752	236	**37.5**

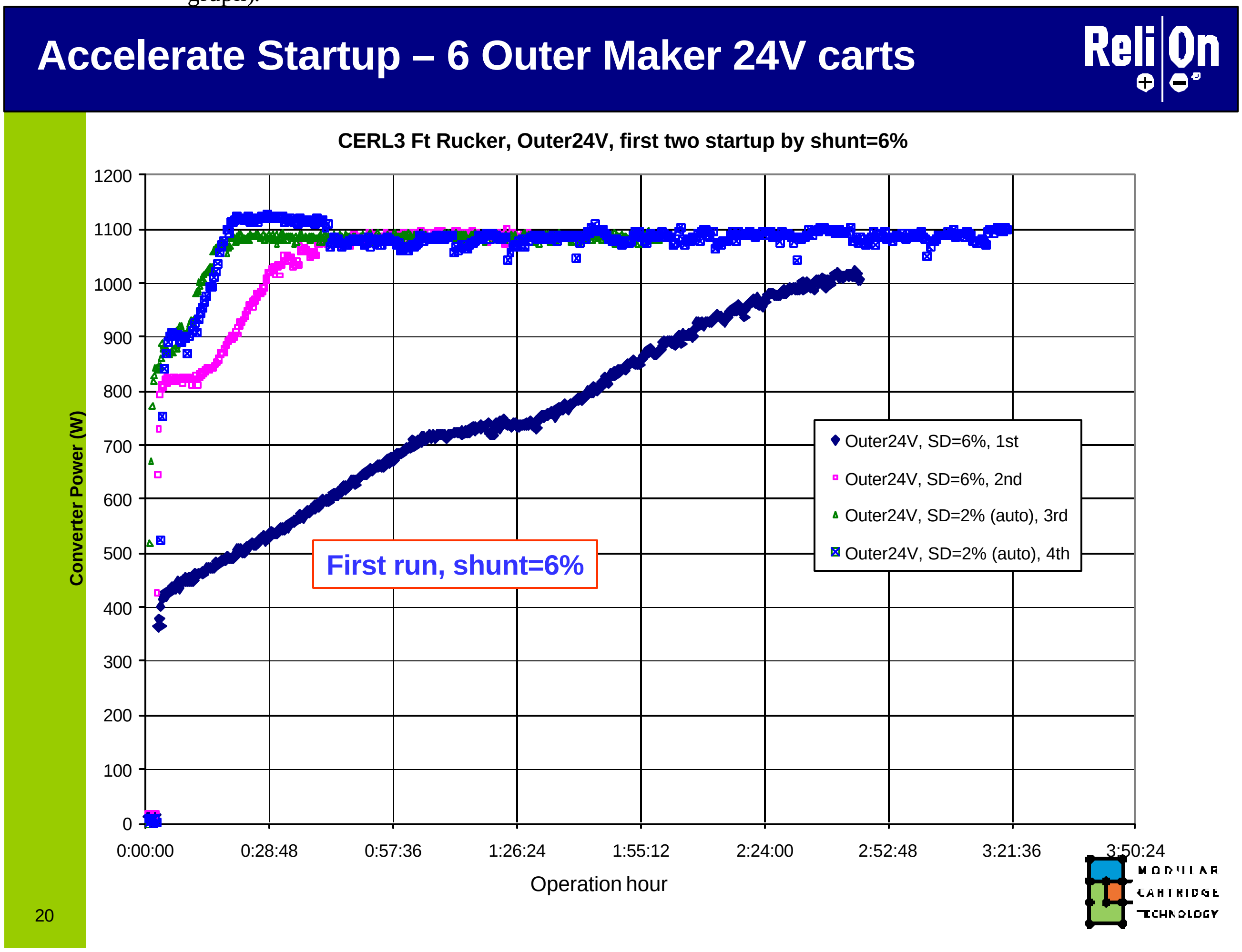
6.3.6 **Graphical reporting for "Glide Slope" ESR supporting Element 1 testing** (See below graph).



7.0 Element 2 - Additional ReliOn Tests

7.1 CERL III, Ft Rucker cartridges were also used to develop accelerated startup procedures for cartridges that have been left dormant or un-used thus becoming dehydrated. Experimentation was performed with alterations to the shunting cycle (ref section 4.2). The graph shown in section 7.2 expresses the results of a 6% shunt on “Outer Marker” cartridges.

7.2 Graphical reporting for “Outer Marker” cartridges supporting Element 2 testing (See below graph).



8.0 Conclusions

8.1 Element 1 test conclusion(s) –

8.1.1 The CERL3 Ft Rucker cartridges that were stored in units and in the field for 18 months were very dry. It took 6 hours on one system set (6) of cartridges and 18 hours on another system set (6) from startup to reach net 1 kW output using the auto startup procedure. After sufficient run time, the startup time reduced to less than 20 min for all 4 sets of cartridges as is specified on all the J-48 Fuel Cells. The re-hydrated state of the cartridges was realized through non-recommended operational practices. However, based on our testing and evaluation at this date, the cartridges are now fully reconditioned to full power capacity and no apparent damage has resulted.

8.1.2 It should be pointed out, however, that ReliOn typically sizes fuel cell solutions with some amount of overhead to quickly meet the power required by the equipment. The typical load for the ILS equipment at Ft. Rucker was approximate 300 watts, and in this scenario even our severely dehydrated systems would have responded as an effective backup solution.

8.1.3 As noted in the written and graphical reporting, there are significant differences between the start up time when comparing Middle Marker Cartridges to the Glide Slope cartridges. This delta or difference can't be explained at this time as there are too many uncontrolled variables with the Fuel Cells when they were in the field at Ft. Rucker sitting dormant for approximately 18 months.

8.2 Element 2 test conclusion(s):

8.2.1 According to our previous test results, increasing the shunt duty cycle could speedup the startup process and re-hydration of dry cartridges. It was found that shunt=6% (shunt defined in section 4.0) increased startup speed by 4 times compared to regular shunt=2% for the unconditioned new cartridges.

8.2.2 The accelerated startup procedure with the shunt=6% was applied to two sets of Ft. Rucker dry cartridges. The accelerated startup procedure reduced startup time by almost 3 times compared to the standard procedure for the cartridges with similar initial hydration status.

8.2.3 The accelerated startup procedure only involved code change and "could" be easily applied to systems in the field if further testing concludes this approach to be favorable.

8.3 Overall Conclusions:

8.3.1 ReliOn has completed testing outlined in Contract Modification Request (CERL-BAA-FY03).

8.3.2 The cartridges remaining after the decommissioning of CER III, Ft Rucker has provided useful information into the affects on performance from dormant/dehydrated ReliOn J48 Fuel Cell systems with Proton Exchange Membranes (PEM) cartridges.

8.3.3 Upon initial or 1st day start up, the lack of use resulted in cartridges that were unable to produce full specified power within the time specified for a system. However, after running the units, the cartridges were able to be reestablished and provide full power within acceptable times.

8.3.4 At this time, ReliOn has not attained enough data to publish the frequency of exercise cycles for its Fuel Cells in various ambient conditions in order to keep the cartridges hydrated. However, as a general rule we now specify a bi-annual exercise cycle of sixty (60) minutes per system.

8.3.5 Running the ReliOn Fuel Cell results in water and/or hydration of the cartridge membranes. The 6% shunt did in fact accelerate the re-hydration of the cartridges under test. As discussed previously, a "shunt" increases the production of water or hydration and allows the cartridge(s) to full power more rapidly than standard "shunting" when cartridge dehydration occurs.

8.3.5.1 The modification to shunting practices from 2% to 6% resulting in decreased time to hydrate the cartridges is still experimental, but provides an excellent starting point for additional work in this area.

End Reporting for Section 16.0, Additional Research/Analysis

17.0 Conclusions/Summary

Between the curtailment of acceptance testing in 2004 and removal of the equipment in 2006, the fuel cell cartridges remained dormant in a harsh environment for over 18 months, well beyond the quarterly exercise requirement designed to keep the MEA components conditioned and hydrated. Although initial restarts of these cartridges showed an extended time period (up to 18 hours in one case) to reach full power output, they could be fully reconditioned and returned to initial start-up and power output specifications. The CERL3 Ft Rucker cartridges that were stored in units and in the field for 18 months were very dry. It took 6 hours on one system set (6) of cartridges and 18 hours on another system set (6) from startup to reach net 1 kW output using the auto startup procedure. After sufficient run time, the startup time reduced to less than 20 min for all 4 sets of cartridges as is specified on the I-1000™ fuel cells. The re-hydrated state of the cartridges was realized through non-recommended operational practices. However, based on our testing and evaluation at this date, the cartridges are now fully reconditioned to full power capacity and no apparent damage has resulted.

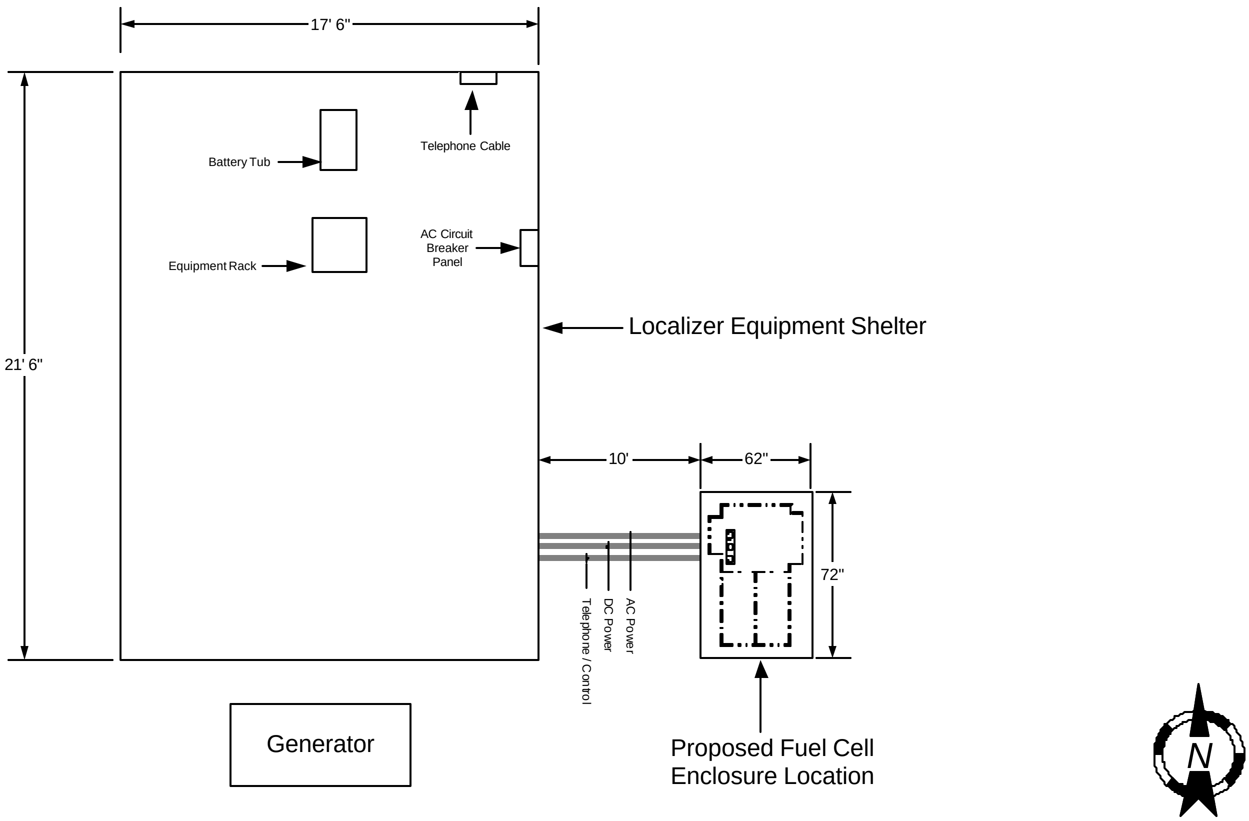
Appendix

Appendix I: Electrical connections for each of four sites

APPENDIX I

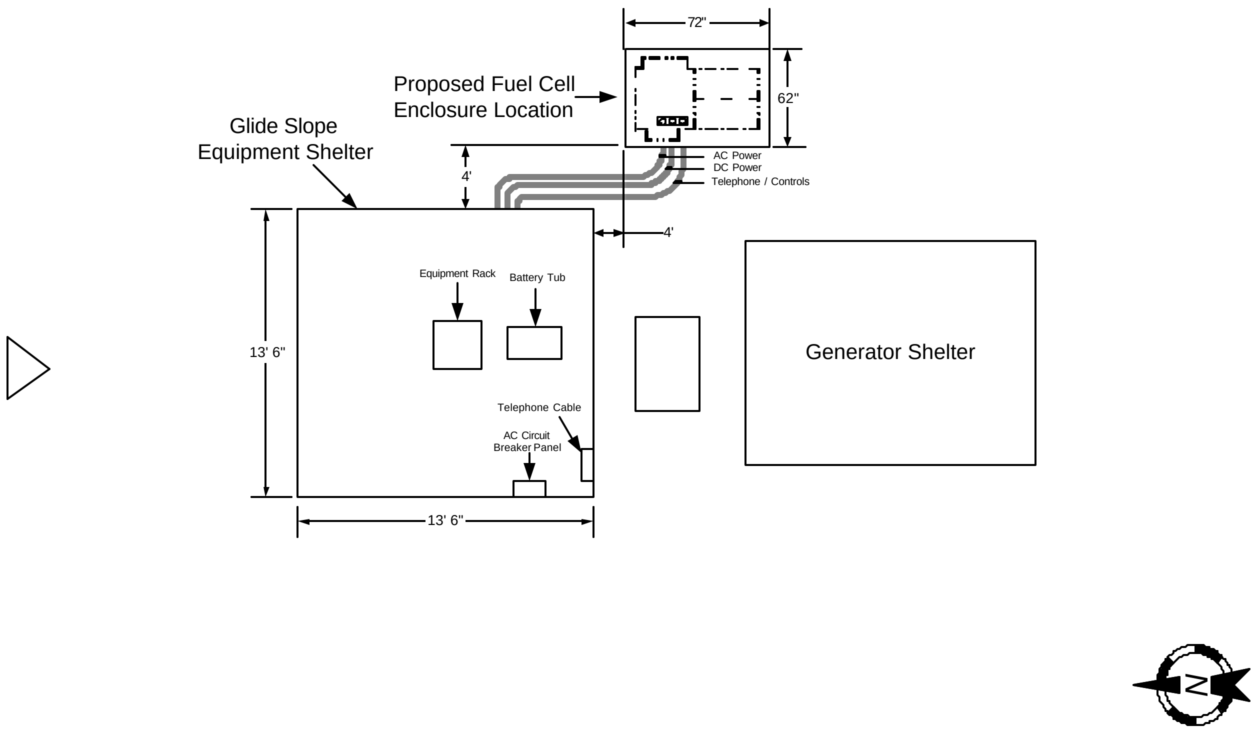
Localizer:

Load size: 50W – 200W



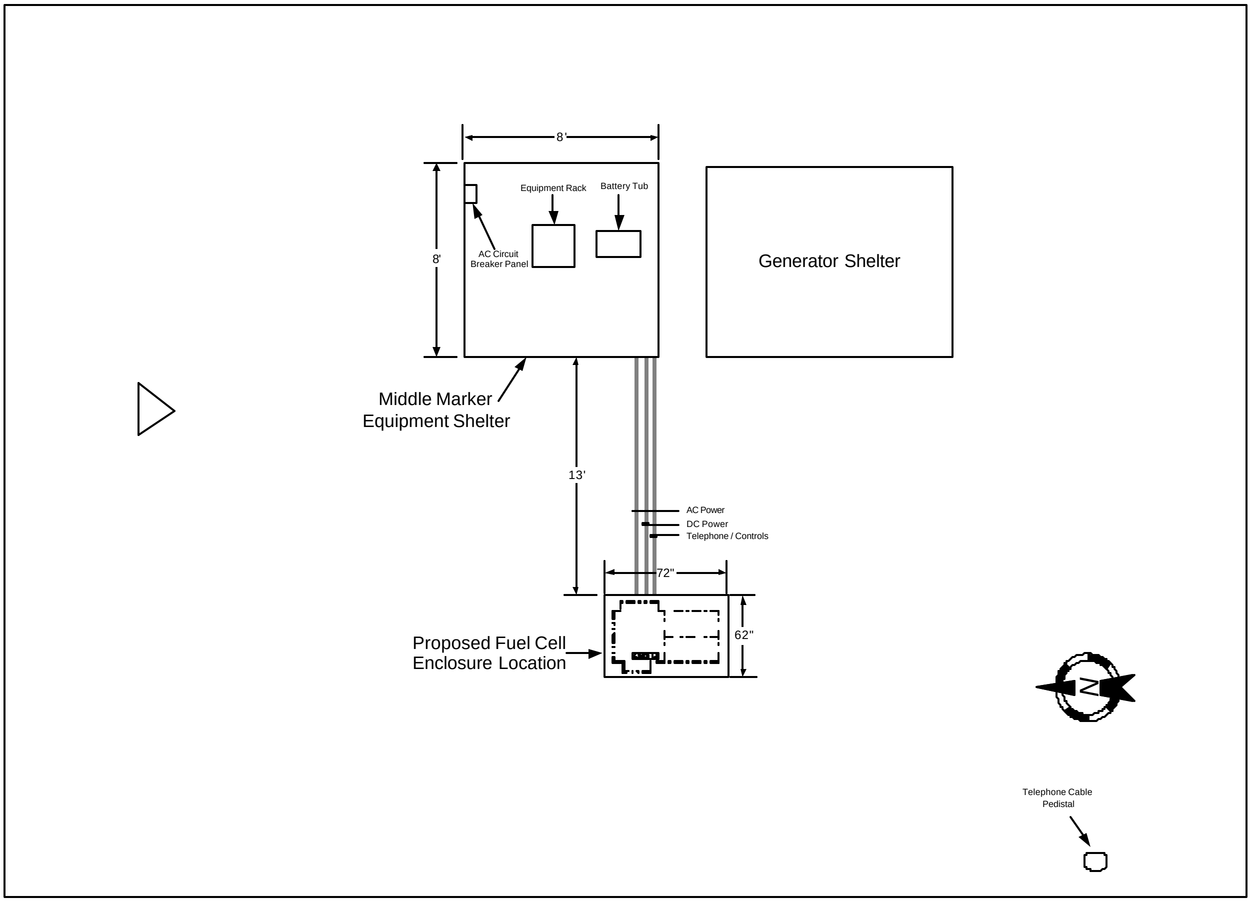
Glide Slope:

Load size: 50W – 200W



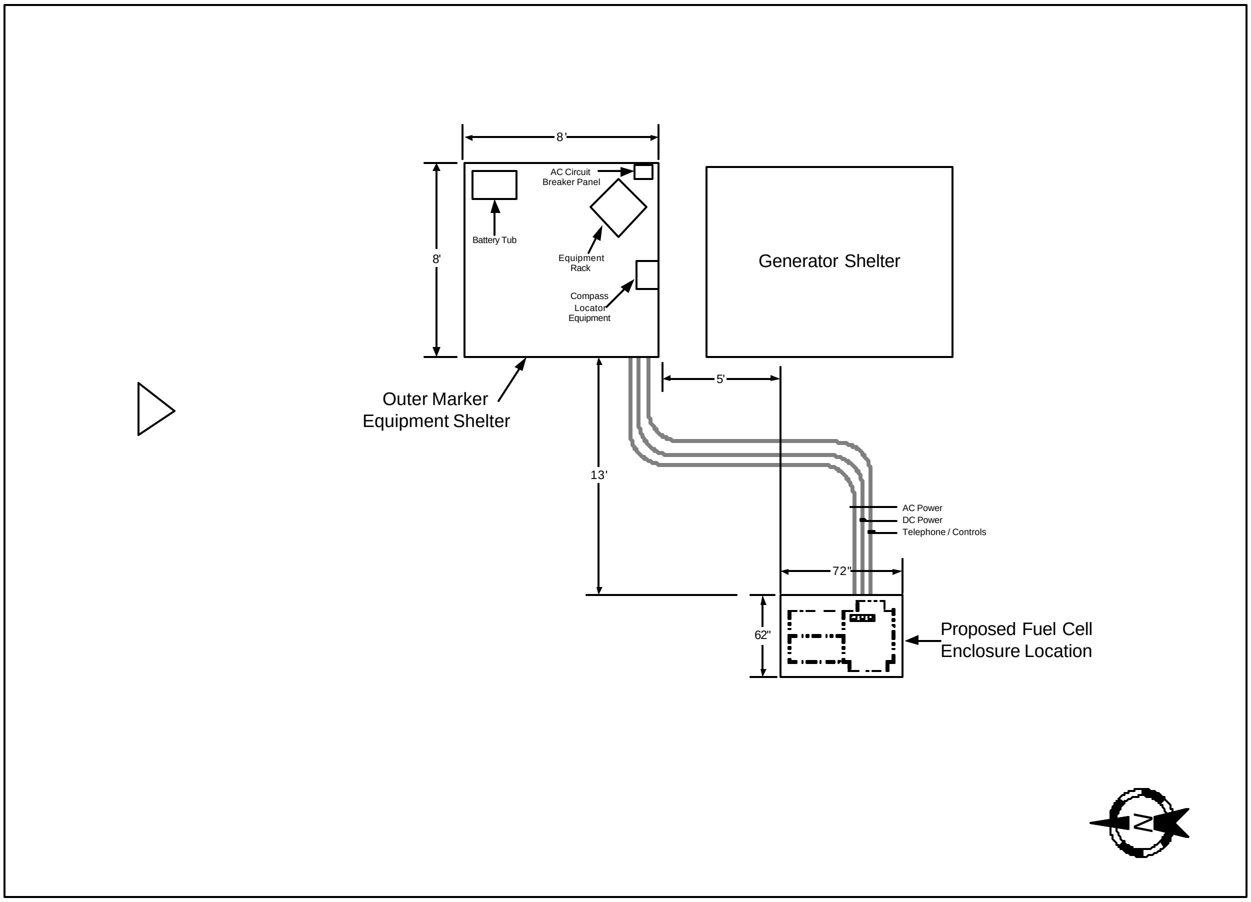
Middle Marker Beacon:

Load size: 50W – 200W



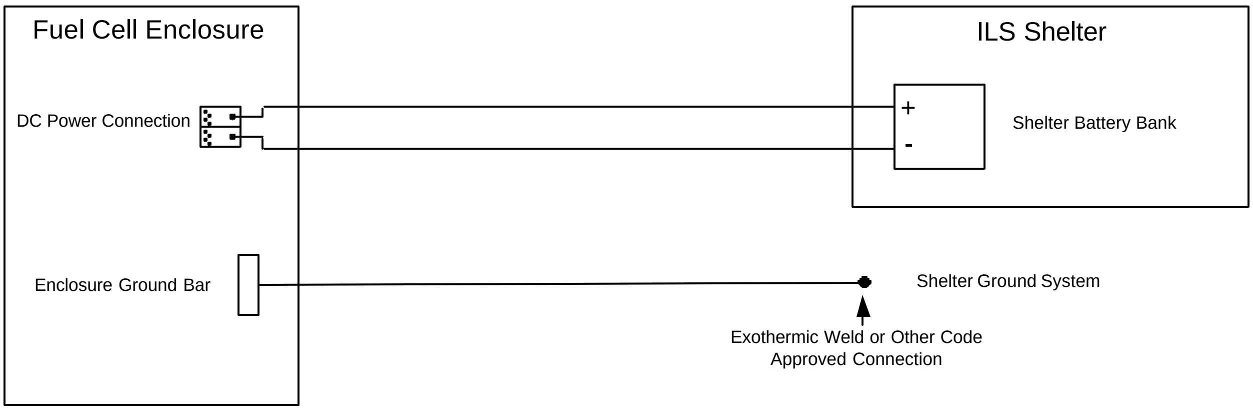
Outer Marker Beacon:

Load size: 50W – 200W

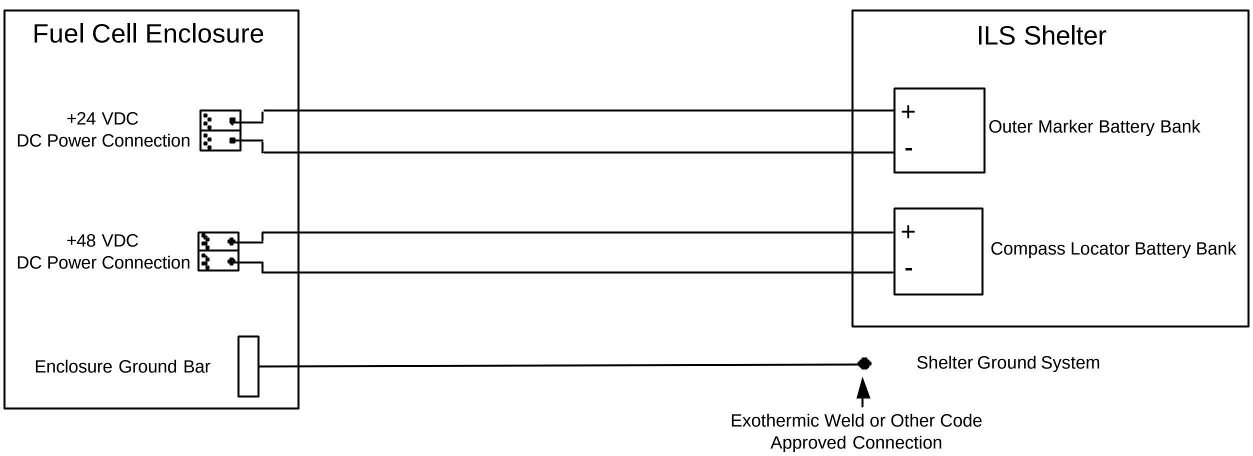


Electrical Connections:

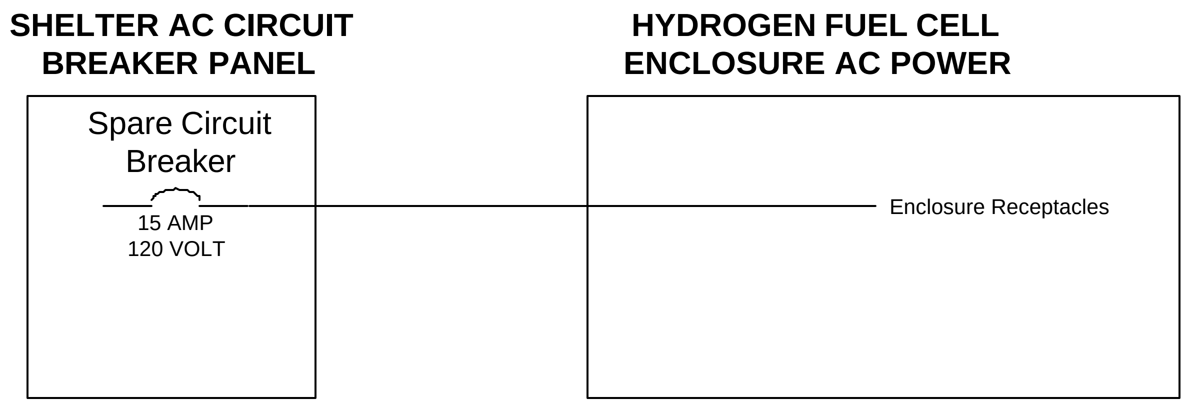
Standard DC Power Connections



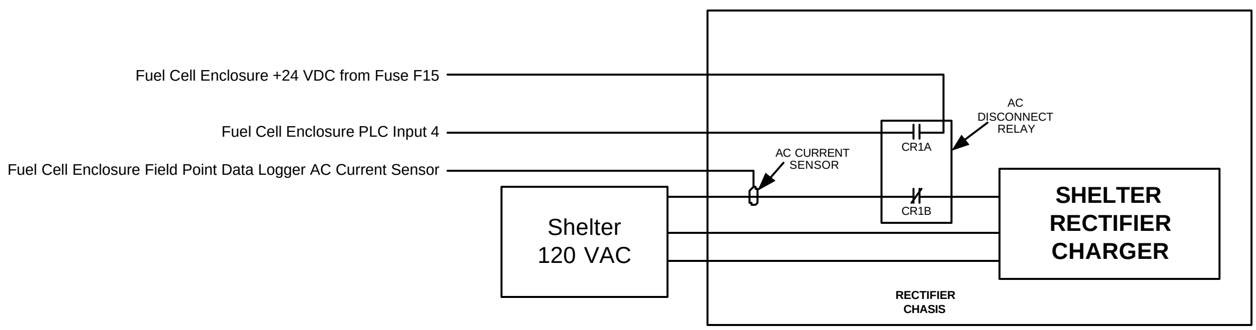
Outer Marker DC Power Connections



AC Power Connections



Standard Rectifier AC Power Disconnect Connections



Standard Rectifier AC Power Disconnect Connections